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ELECTRICAL POWER MANAGEMENT FOR RECHARGING MULITPLE BATTERY-POWERED COMPUTERS

Cross References to Related Applications

This application claims the benefit of U.S. Provisional Application No. 60/267,250 filed February 8, 2001.

Field of the Invention

The present invention relates to electrical power management of available electrical power for recharging internal batteries used with a plurality of battery-powered computers.

Background of the Invention

Wireless computer networks are used in many applications, such as educational, commercial and industrial environments. A typical, basic wireless computer network consists of a server-computer and a plurality of battery-powered client-computers that all communicate via a wireless radio communication link with the server-computer through an air port antenna. The communications may be direct between a client-computer and server-computer, or between a client-computer and network access hardware that communicates with the server-computer. Typically, the client-computers are laptop or notebook style computers and are powered solely from internal rechargeable batteries. An advantage of the wireless computer network is that the portable computers can be moved about while in use without being tethered by

power or data cables, as long as the portable computer is within communication range of the server-computer and is powered by a sufficiently charged battery.

Eventually, the batteries in the portable computers will need to be recharged. Depending upon the application environment, this may result in a large number of portable computers being recharged at one time. For example, in a secondary school application, a classroom populated with thirty portable computers that are used by the students during the day will all be recharged at the end of the school day. The number of portable computers that will be recharged quickly multiplies when numerous classrooms in a school utilize wireless computer networks. Thus, the power burden on the school's electrical system can be substantial when recharging commences.

In many existing buildings, the electrical distribution systems are not designed to support these significant clustered power requirements that generally occur as a result of this technology. Therefore, substantial modifications to the building's electrical distribution system are required to accommodate the clustered recharging of the batteries. Failure to properly modify the building's electrical distribution system for the recharging process can result in the tripping of circuit breakers due to circuit overloads, or can lead to potential electrical fire hazards.

For new construction, the building's electrical distribution system could be oversized to accommodate the clustered recharging of the batteries. However there are favorably time periods during a day, for example evening and early morning hours that can support recharging of the batteries without the additional construction expense of an oversized electrical system. The problem is effectively utilizing these favorably time periods for battery charging.

Therefore, there exists the need for relatively inexpensive electrical

power management apparatus and method for recharging a plurality of multiple battery-powered computers.

Brief Summary of the Invention

In one aspect, the invention is an apparatus and a method for recharging batteries used with a plurality of multiple battery-powered computers wherein the recharging process is managed on the basis of available electrical power capacity for recharging; the number of batteries to be recharged; and the time available for recharging the batteries.

These and other aspects of the invention will be apparent from the following description and the appended claims.

Brief Description of the Drawings

For the purpose of illustrating the invention, there is shown in the drawings a form that is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIG. 1 is a simplified schematic of one example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 2 is an example of one layout of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 3 is a simplified schematic of another example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 4 is a simplified schematic of another example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 5 is a simplified schematic of another example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 6 is a simplified schematic of another example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

FIG. 7 is a simplified schematic of another example of an electrical power management apparatus for recharging multiple battery-powered computers in accordance with the present invention.

Detailed Description

There is shown in **FIG. 1** a first example of an electrical power management apparatus **10** of the present invention. For purposes of illustration only, and not for limiting the scope of the invention, in this example, there are thirty battery-powered computers **30** having internal batteries that require recharging. For simplification, only six of the thirty battery-powered computers are illustrated in **FIG. 1**. There are ten battery-powered computers in each of the three computer groups **31, 32** and **33**. Designated UTILITY POWER SOURCE is typically provided by a 15- or 20-ampere rated branch circuit. While this ac power source is usually rated at 120-volts, 60 Hertz, other rated sources can be suitably converted for use with an embodiment of the electrical power management apparatus **10** of the present invention. In this illustrative example, utility ac power is provided to the line terminals of switching elements **14, 16** and **18** of apparatus **10**. The switching elements may be electromechanical devices, such as relays, or suitable solid state switching devices, such as power transistors or silicon-controlled rectifiers. Controller **12** functions as controls means for the three switching elements. Electrical conductors **21, 22** and **23** selectively

provide utility power from the load terminals of switching elements **14**, **16** and **18**, respectively, to electrical bus elements **25**, **26** and **27**, respectively. Each electrical conductor **29** provides utility power from a bus element to a battery-powered computer **30**. For battery-powered computers **30** that have a self-contained ac-to-dc rectifier and accept external ac power, conductor **29** may be a flexible cord with a plug that connects to the ac adapter receptacle on the battery-powered computer. Alternatively, for battery-powered computers **30** that accept external dc power, an external ac-to-dc rectifier **35** (commonly referred to as a power supply), as diagrammatically shown in **FIG. 1** can be provided in series with conductor **29**. Bus elements **25**, **26** and **27** may be a bank of power receptacles that are selected to mate with a plug on conductor **29**. In alternative examples, conductor **29** may be an electrical fitting that mates directly to a power receptacle on battery-powered computer **30**.

In order to limit current drawn by the discharged batteries in computers **30**, controller **12** will selectively open and close switching elements **14**, **16** and **18** by control lines **15**, **17** and **19**, respectively. As shown in **FIG. 1**, switching element **14** is in the closed position to provide charging current to the ten computers in group **31** as further described below, while switching elements **16** and **18** remain open so that the twenty computers in groups **32** and **33** are not connected to utility power and are not charging. Controller **12** can be configured with timing circuit means so that switching elements **14**, **16** and **18** are individually closed in rotation for a sufficient period of time to provide a substantially full recharge of the batteries in all the computer groups. Optionally, if the magnitude of current is sensed in electrical conductors **21**, **22** and **23** and/or electrical conductors **29**, as further described below in other examples of the invention, a combination of switching elements may be closed at the same time so long as that the total ac

current drawn for battery charging by all simultaneously connected computers **30** does not exceed a pre-selected maximum current from the ac power source. By way of example, the pre-selected maximum current value can be inputted with a suitable input device (such as a keyboard interface) and simulated in a comparator circuit in the controller. The total ac current draw for battery charging can be sensed with current sensing means and inputted to the comparator circuit. If the total ac current draw does not exceed the pre-selected maximum current value, logic circuitry in controller **12** can be used to selectively open and close switching devices **14, 16** and **18**. At the completion of providing a substantially full recharge of all thirty batteries in the three groups, the controller may optionally be configured with control means for closing all three switching elements so that a low-current trickle charge can be maintained to all of the batteries. Thus, all batteries in the battery-powered client-computers are recharged over a time period that is available for charging.

As disclosed above, the selection of three computer groups, with each group having ten battery-charged computers, is used simply for illustrative purposes. The number of computer groups, and therefore the number of switching elements serving the computer groups, and the number of battery-powered computers in each group will vary depending upon a particular application, and will still be within the scope of the invention.

FIG. 2 illustrates one example of the layout of apparatus **10** relative to battery-powered computers **30**. In this example, apparatus **10** is provided in an enclosure **40** that is mounted adjacent to shelves **41** for storing the battery-powered computers **30** while their internal batteries are being charged. In alternative examples, enclosure **40** may be separately wall or floor mounted. Additionally, the apparatus **10** in all

examples illustrated in this specification may incorporate an ac-to-dc rectifier for direct charging of a battery when it is removed from its battery-powered computer **30**. In this event, the layout would also include one or more dc battery charging receptacles that are configured for connecting to the removed batteries. One or more dc electrical bus elements would be connected to the controlled dc output of the ac-to-dc rectifier by dc switching elements that would be controlled in a power management process similar to that for the ac switching elements in the various examples in this specification. Alternatively ac switching elements could be provided at the input to the rectifier in lieu of (or in addition to) dc switching elements at the output of the rectifier. Input power to the rectifier would be from ac power line **11**. A charging regulator circuit can be included with the ac-to-dc rectifier to regulate the dc output of the rectifier and provide for various charging modes, such as fast, slow or trickle charge. Additionally, apparatus **10** may incorporate one or more electrical loads with means for switching a removed battery between the load and the dc output of the rectifier. With this arrangement, one or more deep (substantially full) discharge (via the electrical load) and recharge (via dc current from the rectifier) cycles of the battery can be provided during an available charging period. This is of particular value when the types of batteries being used require occasional deep cycling to maximize battery life. If battery-operated computers **30** accept external dc power, ac-to-dc rectifiers **35** can be included in the interior of enclosure **40**.

In one embodiment of the invention, the storage area for the battery-powered computers is physically isolated from the interior of enclosure **40** to provide isolation of live electrical components from individuals who would connect and disconnect computers **30** to and from apparatus **10**. Power conductors **29** (either ac or dc depending

upon the input configuration of computer **30**) can be run through conduits between the interior of the enclosure and the storage area.

FIG. 3 illustrates another example of the present invention. In this example, a 20-ampere branch electrical circuit is provided to apparatus **10** from the building's utility power source. Timer **70** is, for example, a twenty-four hour timer that operates associated contacts (switching element) **T**. Timer **70** is selectively set to close contacts **T** at the time when battery recharging can be started. Timer **70** is also selectively set to open contacts **T** at the time after which battery recharging will no longer be allowed. Contacts (switching element) **CS1** remain normally closed unless **CS1** current sensor **71** (main current sensor) senses current flow in line conductor **11** that is equal to or exceeds a preset limit, such as 18 amperes, for the illustrated 20-ampere rated circuit.

As long as switching elements **T** and contacts **CS1** are closed, the battery-powered computers **30** that are connected to electrical bus element **25** (group **31**) will have their internal batteries connected to charging ac (or dc, if external ac-to-dc rectifier **35** is provided) power provided from the 20-ampere branch circuit. **CS2** current sensor **72** is set to sense a first low current flow point in electrical conductor **21**. For example, the **CS2** low current flow point may be set at 5 amperes. When the current flowing in conductor **21** is equal to or less than 5 amperes, contacts (switching element) **CS2** will close, which will begin the charging of internal batteries for computers **30** connected to bus element **26** (group **32**).

CS3 current sensor **73** is set to sense a second low current flow point in electrical conductor **22**. For example, the **CS3** low current flow point may be set at 5 amperes. When the current flowing in conductor **22** is equal to or less than 5 amperes, contacts (switching element) **CS3**

will close, which will begin the charging of internal batteries for computers **30** connected to bus element **27** (group **33**).

In this charging scheme, additional groups of internal batteries begin to charge as the currently charging batteries reach full charge and the charging current that they draw is reduced. As additional groups of internal batteries are charged the previously charged batteries remained connected to the ac power source to receive a trickle charge.

The three-stage charging scheme can be expanded (or contracted to two-stages) to more stages as required for a particular application. Generalizing, any number of electrical bus elements can be provided. Battery-powered computers **30** are distributively connected to the electrical bus elements. If the computer accepts an external dc power source, in one embodiment, the ac input of an ac-to-dc rectifier **35** (commonly referred to as a power supply) is connected to the electrical bus elements and the computer is connected to the dc output of the rectifier. An electrical bus element and the connected (directly or indirectly via the rectifier) group of computers form a charging priority circuit that receives ac charging current from line conductor **11** through timer switching element **T** (and main switching element **CS1**, if used). All of the charging priority circuits are arranged and controlled so that charging begins with the batteries in the group of computers connected to a first charging priority circuit. When the charging current in the first charging priority circuit is at or falls below a selected value, charging of the batteries in the group of computers connected to the next charging priority circuit begins. This stepped process of permitting charging of the batteries in the group of computers connected to the next charging priority circuit continues until charging is accomplished in all of the charging priority circuits. Current sensing to determine when the selected value of charging current has been reached for each charging

priority circuit is accomplished by a group charging current sensing device. Each group charging current sensing device is associated with a group charging current switching device that is located in the next charging priority circuit. When the selected value of charging current is achieved, the group charging current switching device closes to allow charging current in the next charging priority circuit.

FIG. 4 illustrates another example of the present invention. In this example, current sensors **28** are placed in ac power line **11**, and/or electrical conductors **21**, **22** and **23**, and/or electrical conductors **29**. Each provided current sensor sends a current magnitude signal to controller **12** so that control means in controller **12** can better evaluate the present charging state of each battery-powered computer, and/or the present charging state of each computer group, and/or the total instantaneous line current draw for all computer groups. With respect to battery-operated computers **30** that accept external dc power via an external ac-to-dc rectifier as described elsewhere herein, current sensing can be accomplished at the ac input to the rectifier or the dc output of the rectifier. Monitoring these current levels will allow controller **12** to make a better evaluation of what computer groups require additional supply current that may be limited by available line power. In an arrangement where each computer group consists of only one battery-powered computer (i.e., dedicated individual computer charging control) controller **12** would be capable of high efficiency power management during the charging process by monitoring the charging rate and time, and battery charge state, of the battery or batteries in each computer. Further dedicated computer charging control in each line **29** could include a theft detection function. For example, if the current sensor in one of conductors **29** for a particular battery-powered computer senses a zero current (or alternatively, a voltage sensor sensing no computer load)

condition, then the battery-powered computer has been detached from its charging conductor **29**. The event could be inputted to the executing power management computer programs, as further described below in other examples of the invention, and reported via an appropriate data link to appropriate personal.

FIG. 5 illustrates another example of the present invention. In this example, controller **12** is replaced by an input/output (i/o) device **51** that transmits and receives data signals to/from a computer (identified as SERVER COMPUTER in the drawing) **52** via data signal line **53**. Alternatively, the data communications between the i/o device **51** and computer **52** may be via wireless network devices. In this configuration, computer **52** would execute power management computer programs that would send commands (output control signals) via appropriate hardware to the i/o devices for opening and closing of switching elements **14**, **16** and **18** as set forth in other examples of the invention. If current sensing is incorporated into this example of the invention, i/o device **51** could transmit sensed current levels to computer **52** wherein operating power management programs would further adjust recharging times for the batteries. With appropriate data coding for each battery-powered computer **30**, the power management programs could develop a data log of each battery's charging profile and alert the operator of computer **52** regarding the present condition of a particular battery. For example, the program could determine when an end-of-life condition is approaching for a battery and recommend to the user that the battery be replaced.

Even if the batteries in all computers **30** are recharged simultaneously, a battery management computer program module for the power management programs would be an advantageous improvement. The battery management computer program module would include a database of battery parameters and be capable of tracking the service life

of each battery to optimize the lifecycle performance of a battery. For example, certain types of batteries must periodically have deep cycle discharge and recharge conditioning to prolong the life of the battery. Battery discharge could be achieved by leaving computers **30** in an operating state during the available period for charging. Between deep cycle recharges by apparatus **10**, the server-computer could power up computers **30** via the wireless network (i.e., run hard drive and other peripherals in computers **30**) to fully discharge their internal batteries. Apparatus **10**, under control of the power management programs, would manage selective discharge and recharge of computers **30** during the available charging time period. Optimal lifecycle battery performance could be maintained without user intervention.

FIG. 6 illustrates another example of the present invention wherein the power management system of the present invention would be provided in multiple locations or rooms of a building, for example, a school building wherein each classroom had an apparatus **10**. By way of illustration and not limitation, **FIG. 6** illustrates a two-room arrangement. Computer **52** in first room is able to communicate with computer **52a** in a second room by wireless communication, hard data wiring, or data signals transmitted through the building's electrical distribution system. In this example, battery charging of all battery-powered computers in the building could be efficiently scheduled throughout the available charging time period. For example, one classroom may utilize the battery-powered computers **30** for night classes, or other evening uses, after the computers have been in use all day via battery power. The power management computer programs would give charging priority to the classroom that would be used for night classes while batteries in the other classrooms are charged later in the evening.

Additionally the power management computer programs could coordinate routine client battery-powered computer program maintenance (e.g., program updates on the client computers) by the server-computer during the programmed recharging process.

FIG. 7 illustrates another example of the present invention wherein apparatus **10** initially rectifies utility power in AC/DC RECTIFIER **61** and stores dc power in battery bank **62**. When battery charging commences for battery-powered computers **30** that accept external dc power, battery bank **62** could supply the required dc power. In this configuration, charging power may be stored in battery **62** when convenient for the utility ac power source and selectively supplied to computer groups **31**, **32** and **33** by switching elements **14**, **16** and **18**, respectively when charging is permissible. Alternatively, a combination of stored dc power and rectified line power can be used to charge the batteries. Regulator **63** can optionally be used to control charging parameters, such as charging voltage level and rate. In the event that battery-powered computers **30** accept external ac current, a dc-to-ac inverter can replace regulator **63**. The inverter would invert dc current from battery bank **62** into an ac current that is selectively supplied to computer groups **31**, **32** and **33** by switching elements **14**, **16** and **18**, respectively. In alternative examples of the invention, a dedicated battery bank and switching element (and supporting components, such as the regulator or inverter, if required by the configuration) may be provided for the charging of computers **30** in each computer group via their connected electrical bus element.

Ac to dc rectification, whether it is accomplished by a bulk rectifier, such as rectifier **61**, or distributed rectifiers, such as rectifiers **35**, or rectifiers integral to battery-operated computers **30**, introduces a substantial distortion on ac power line **11**. Optionally, in all examples of

the invention, ac line filtering means, including active and passive filter topologies, can be included in apparatus **10** to attenuate line distortion during the charging time periods.

The power management system of the present invention may also serve as a convenient and energy efficient bulk "charging station" on an organizational-wide basis. For example, on business and university campuses, campus-wide wireless air networks are in operation. Apparatus **10** could be strategically located at various locations throughout the campus to provide centralized charging stations. This example of the invention could optionally include security locking means for computer **30** left at the station for charging and toll metering of individual computer charging. Apparatus **10** could be powered from a readily available 15- or 20-ampere building receptacle and charge many more computers **30** with a time-power management scheme than would otherwise be possible, and do so in a safe and efficient manner.

The power management system of the present invention is also applicable to an arrangement of computers **30** that are connected to apparatus **10** while they are in use. In this application, if the available utility power source is of limited capacity and cannot supply sufficient operating power to all of the computers, apparatus **10** will simultaneously operate and charge selected computer groups while the remainder of the computer groups operate solely from internal batteries that were previously charged.

The examples of the invention include reference to specific electrical components. One skilled in the art may practice the invention by substituting components that are not necessarily of the same type but will create the desired conditions or accomplish the desired results of the invention. For example, single components may be substituted for multiple components or vice versa, or a switching element have a

normally closed configuration can be converted to a normally open configuration by using the normally closed switching element in the power circuit of a relay or other switching element with a normally open configuration.

The foregoing embodiments do not limit the scope of the disclosed invention. The scope of the disclosed invention is covered in the appended claims.